Behavioral Response Study

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LONG-TERM GOALS

This is the report of the first behavioral response study to be carried out on beaked and pilot whales in which these animals were exposed to carefully measured doses of underwater sound while their responses were being measured. The study is seen as the first step in a series of similar experiments that are designed to safely identify the behavioral mechanisms that may be involved in the causal chain of events leading from exposure to some types of man-made underwater sound to mass strandings of beaked whales and to test whether this risk extends to other cetaceans.

OBJECTIVES

The objectives of work undertaken in the past year were to:

- Establish, test and refine new protocols for studying beaked whales using established sound playback experiment paradigms
  - Demonstrate feasibility and safety of study design;
  - Obtain U.S. and Bahamian permits and engage with eNGOs concerning the pros and cons of these specific kinds of playbacks;
  - Collect base-line (control) data to provide a basis for comparison with playback results.

- Define responses of beaked whales, and other species of odontocete whales, to mid-frequency active (MFA) sonar and natural sounds such as those from killer whales. Address the questions:
  - Does the response help narrow the range of hypotheses for the cause of MFA sonar-related strandings?
  - Does the response to MFA sonar differ from the response to killer whale sounds to test whether whales respond to sonar as if it represented a predator?
  - Can responses be used as a safe predictor of risk of injury/stranding from higher level exposures?
  - Do other species also respond in a way that elevates risk of injury/stranding?

- Measure exposure parameters for sounds that evoke a behavioral response
  - Use an acoustic recording tag as the primary method to measure received level at the animal.
  - Measure ship noise on the AUTEC hydrophones, and input these measures to an acoustic propagation model to predict exposure at the animals.

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APPROACH

A Behavioral Response Study took place in the Tongue of the Ocean (TOTO) and at the adjacent Atlantic Undersea Test and Evaluation Center (AUTEC) on Andros Island, Bahamas during August and September 2007 (Fig. 1). AUTEC has a 600-square-mile permanent grid of seafloor hydrophones in the deep ocean canyon of the TOTO where beaked whales are known to occur.

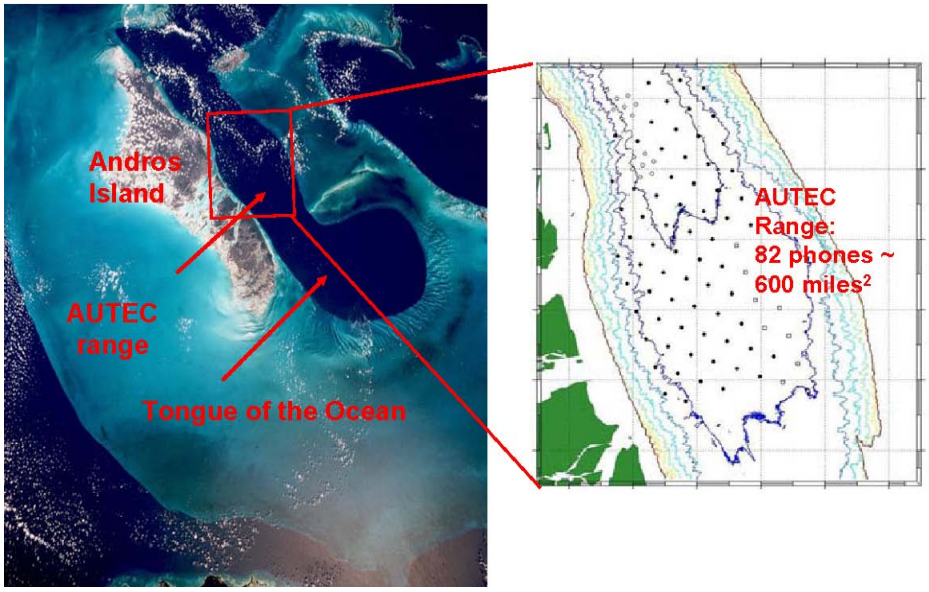
2. 

Figure 1: A GoogleEarth image of the southern Bahamas showing Andros Island and the Tongue of the Ocean, a canyon surrounded by shallow reefs in which the AUTEC Range is located (box). The range is shown in the diagram in the right. There is a 2 nm spacing between the hydrophones which are shown as circles or solid dots.

WORK COMPLETED AND RESULTS

On the whole, these objectives were achieved. The feasibility of the approach was demonstrated, and considerable progress was made with refining the research protocols. As expected, the chance of tagging a beaked whale is highly dependent on weather and wind conditions, as even light winds can make visual detection very difficult. The permitting process in both the U.S. and Bahamas was successfully completed. All the required permits were provided in time for the field effort and the conditions of the permits were compatible with the research plan. Efforts were made to interact with and consult eNGOs in advance of the field program and, while some eNGOs remained resistant to the approach, many were willing to engage in discussions with the research team. Many of the comments and suggestions received will continue to be useful in the development of subsequent phases of the study.

The research protocols used a combination of data sources to measure the behavioral responses of whales to sound. This included: direct visual observation of the whales when at the surface, passive

acoustic measurement of whale behavior when they were acoustically active (for beaked whales this was during deep foraging dives), and detailed behavioral and acoustic observations from suction cup tags attached directly on focal individuals. The objective was to play the simulated sounds of MFA sonar, killer whales, and other control sounds to a sample of animals being monitored using these methods. The sound source level was ramped up gradually as a precautionary measure and to allow for each subject the ability to relate the onset of a response to a specific RL. The estimated received level of sound at the animal was always kept well below the level expected to cause temporary threshold shift.

Data were collected from 10 tag deployments, 6 on Blainvilles beaked whales and 4 on pilot whales. A total of 109 hours of data were collected from tags, 74 hours from beaked whales and 34 hours from pilot whales. The data collected by the tag included sounds produced by the tagged animal, environmental and anthropogenic sounds received by the animal, details of the animals movements in terms of its diving, swimming speeds, changes in orientation and swimming actions.

Playbacks were performed on 3 of the tagged whales, 1 beaked whale and 2 pilot whales. This is a lower total than was anticipated. Long stretches of poor weather incompatible with tagging, especially toward the end of the test period, meant that effective tagging opportunities were greatly reduced from expectation. However, those playback experiments conducted did demonstrate that these methods could safely be used in these species using MFA and biological sounds to generate very detailed information on received exposures and behavioral responses.

Photo-identification of beaked whales in the study region over several years before the study, as well as identification of animals during the study, suggests a degree of residency within the region, with some individuals seen over multiple years.

At this stage, only the results from the playback to the beaked whale have been analyzed extensively. The following is a preliminary summary of what was observed:

- After a pre-exposure dive, a MFA sonar playback was conducted on a tagged, female adult *Mesoplodon densirostris*.
- The MFA playback started at a source level (SL) of 152 dB (dB re 1 µPa at 1 m [rms] for Source Level and dB re 1 µPa [rms] for Received Level, unless otherwise specified), a few minutes after the whale began producing ultrasonic clicks. The SL was then increased by 3 dB every 25 s in a ramp-up procedure, reaching a maximum SL of 212 dB after 9 minutes. The MFA signal was then played back at maximum SL every 25 sec for 6 minutes.
- The first ping detected on the tag and for which received level (RL) could be estimated, had an RL of ~95 dB (Fig. 2)
- After 10 min into the playback, the whale appeared to stop clicking earlier than usual, when the RL at the whale was ~145 dB. The playback continued for several minutes once cessation of clicking was confirmed. The maximum RL recorded at the whale was ~152 dB. Because this dive was so short, she had an unusually low number of whale buzzes (very rapid series of clicks) which are indicative of foraging events.
- The whale then ascended more slowly than usual and, as a result, had a longer than normal ascent.

- The whale surfaced, where her behavior appeared normal. After about 2 hours she started another deep foraging dive (Fig. 2). Once she started clicking at depth, a playback of killer whale sounds was started.
- The killer whale playback started at an initial SL of 130-140 dB, a few minutes after the whale began producing ultrasonic clicks. The SL was then increased by about 5 dB about every 30 sec in a ramp-up procedure, reaching a maximum SL of 190-203 dB after 10 minutes. The killer whale playback was stopped several minutes after the whale stopped clicking, before the ramp up process had reached maximum SL.
- The first killer whale sounds detected on the tag for which RL could be estimated had a RL of ~96 dB (Fig 2).
- The whale stopped clicking about 5 minutes into the killer whale playback, a shorter clicking period than usual. The received level of the killer whale sounds recorded on the tagged whale just before she ceased vocalizing was ~117 dB. The sound exposure at the whale continued for several minutes once the cessation of clicking was confirmed. The maximum RL recorded at the whale was ~134 dB.
- This exposure dive had the shortest overall clicking period, the lowest number of buzzes, the slowest ascent rate, and the longest ascent among the beaked whale deep foraging dives recorded at TOTO during the study from 5 individual whales (Fig. 3).
- As soon as the killer whale playback stopped, the beaked whale started swimming away from the location of the sound source and she continued swimming on a much straighter course than usual, although she made two additional deep foraging dives during this movement, the first of which was 4.8 hours after the killer whale exposure dive. This inter-dive interval is longer than any of the other times between deep foraging dives of *Mesoplodon* recorded during the present study at AUTEC.
- By the time the tag was released from the whale, 10 hours after the end of the dive that contained the last playback, the whale had traveled approximately 20 km (10.8 nm) from the playback location at an average horizontal speed of about 0.5 m/s (1 kt) (Fig. 4). Details of this movement pattern are preliminary and will be improved after the tag data are geo-referenced at several points throughout the record.

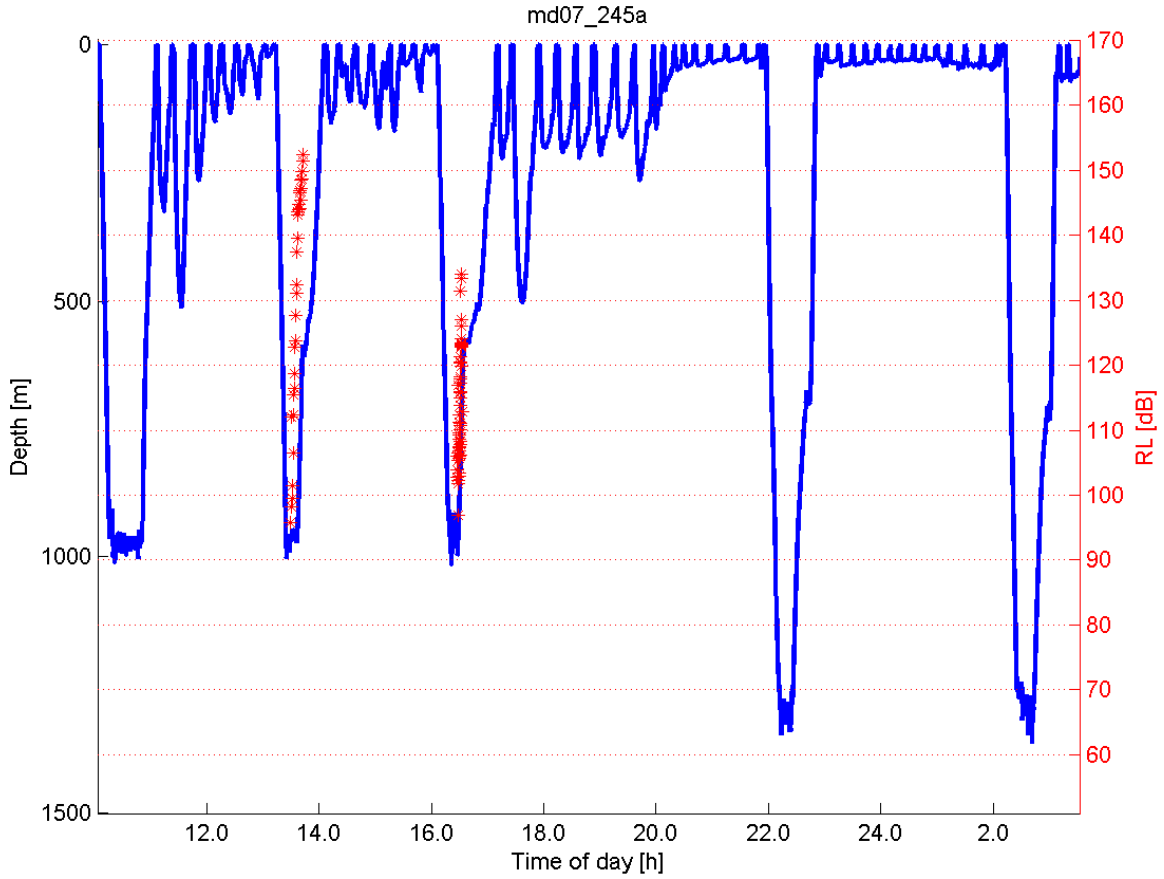


Figure 2: The dive profiles of the female beaked whale involved in the playback. This shows the depth of the whale (blue) during the time that the tag was attached. It shows that the whale made 5 deep (>500m) foraging dives. During two of these dives (numbers 2 and 3) she was exposed to a playback of MFA sonar (dive 2) and killer whale (dive 3) sounds. Each of the red stars shows when the tag on the whale received playback sound and the received sound level (dB re. 1 µPa) as indicated on the right hand axis. It can be seen that the playback sound was ramped up through the deep dive which corresponds to the time when the whales was clicking. The playback was ended in both cases within several minutes of cessation of vocalization.

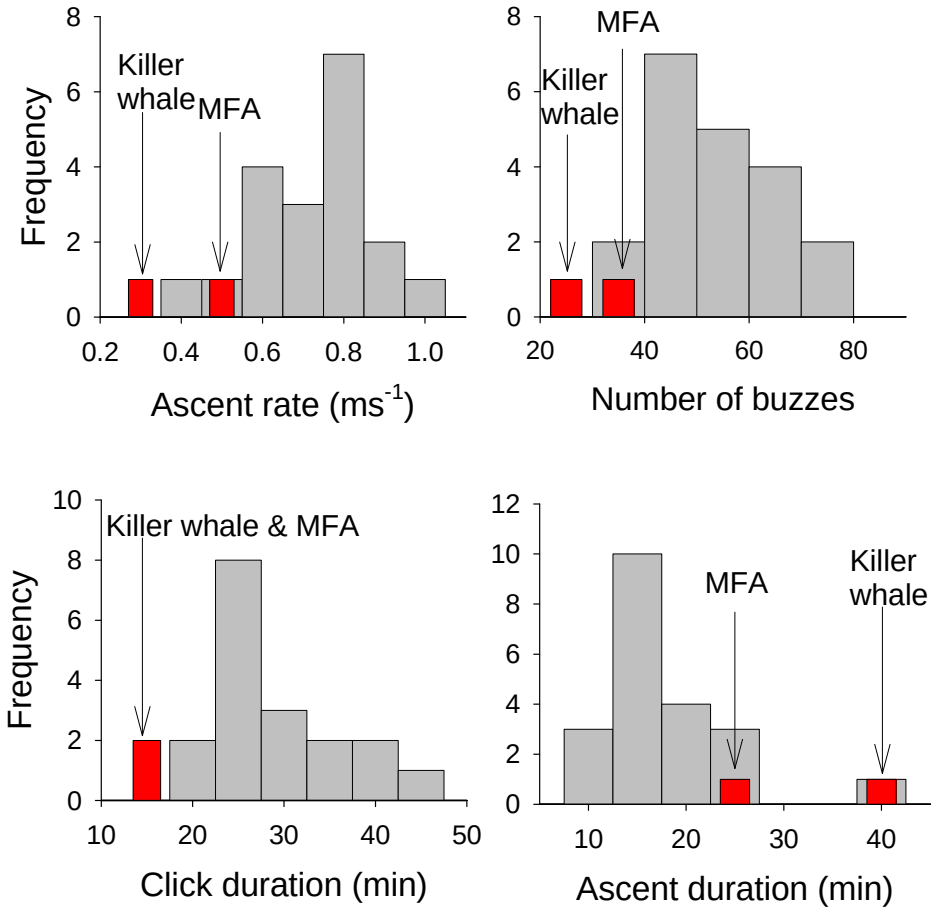


Figure 3: Histograms showing the frequency distributions of four variables measured across all the deep foraging dives for Blainville's beaked whales within the TOTO. The grey bars show those dives made without playbacks whereas the red bars represent the measurements made for the dives when playback occurred.

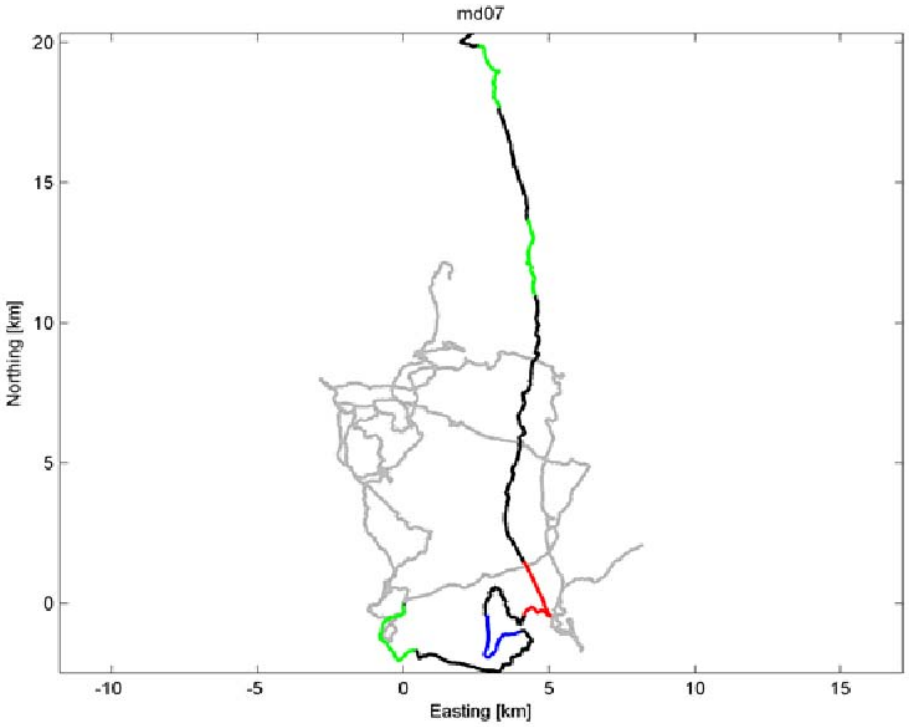


Figure 4: The patterns of movement, shown in a two-dimensional plan view, of four tagged Blainville's beaked whales when the whales made repeated deep foraging dives. These tracks are based upon assumptions about the speed of the whale and of currents, and the details of movements will be improved after points are georeferenced throughout the record. The track shown in multiple colors is of the female adult beaked whale involved in the playback, and this is superimposed on three that are in grey in which there was no playback. Each track covers a similar time period. The black parts indicate parts of the track that were not deep foraging dives. The green sections show the pre- and post-playback dive; the blue section shows the track during the MFA sonar playback and the red section shows the track during the killer whale playback.

IMPACT/APPLICATIONS

These early results have to be interpreted with care because the analyses are preliminary and stem from a single experiment involving the response of one individual. There is also a limited set of baseline data to characterize normal behavior. A greater sample size is required before robust conclusions can be drawn. However, this result helps to narrow the high level of uncertainty about the possible responses of Blainville's beaked whales to sonar and predator calls, and it provides a basis for further experiments to better understand the nature of the response. Nothing in the responses observed to date suggests that the playback experiment presented any risk to the whale. Additional questions that need to be addressed include, but are not limited to:

- Was the prolonged movement away from the sound source after playback of killer whale calls the result of the killer whale stimulus alone or was it influenced by the MFA playback, and the order in which the sounds were presented?

- Do these animals respond in this way to other novel sounds irrespective of whether they simulate MFA sonar or a predator?

- What is the range of acoustic parameters associated with these responses.

It is not possible at this stage of analysis to be sure about the pilot whale responses to playbacks, but it is possible that one of the tagged pilot whales responded.

The study has seen a successful progression toward our main objective which is to characterize behavioral responses that could be used to measure the effects of MFA sonars on beaked whales and other species. While further analyses of the data are required, we believe that we have obtained a relatively clear set of behavioral responses by an adult female beaked whale to the controlled playback of MFA sonar and killer whale sounds. The tags were able to quantify the acoustic exposure associated with the onset of the responses. However, it must be noted that this experiment involved two exposures to a single individual with limited baseline information. Now that we have demonstrated that this experimental paradigm can provide useful information, without harm or undue risk to the animals, additional results using a similar paradigm are needed. Additionally, the absence of negative control stimuli for the study means that this test must be repeated with other stimuli that do not elicit such a response. Such tests would allow us to better understand the sound features that elicit responses.

The field team was fully operational on only 25 percent of the days scheduled for the experiment, mainly because of weather conditions that were not suitable for carrying out tagging operations. Activities related to other AUTEC range users had less impact than weather but were an important operational constraint. Tagging was successful on 60 percent of days when weather conditions were suitable for tagging, suggesting that, given appropriate weather, tagging has a high success rate at AUTEC. Historical weather records suggest that the study had about 50 percent of the opportunities to operate in 2007 that it could have expected based on average measurements of sea state over the previous 7 years.

The protocols initially proposed for playbacks were carried through without major in-field modification. However, the detailed action list and control procedures for the playback protocol has been refined and modified as a result of this experience. The experimental procedures were refined throughout the study and have resulted in a number of recommendations for future research.

The post-playback mitigation and monitoring observations, both vessel-based and aerial, were conducted at the start and end of the study and after both playbacks to ensure that there were no injured or stranded marine mammals in and around a large area surrounding the location of each playback. In some cases, weather and practical considerations extended the periods of time over which this monitoring was conducted, but for all playbacks there was extensive monitoring of both the waters and surrounding shorelines. No distressed, injured, or stranded animals were detected at any time.